MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2 , 2022/2023

EPM2036 – CONTROL THEORY

(RE)

12 JULY 2023
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 4 **pages** excluding cover page with **4 Questions** only.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) An open-loop system has an input $x(t)$ which represents the amount of airflow into a container and an output $y(t)$ which represents the temperature of the container. The open-loop system has an input-output relationship given by

$$\frac{d^2y(t)}{dt^2} + 6\frac{dy(t)}{dt} + 5y(t) = 25x(t)$$

(i) Find the open-loop system transfer function $G(s)$. [7 marks]

(ii) Find the zero(s) and pole(s) of the open-loop system, including those at infinity (if any). [6 marks]

(b) One objective of control systems is to ensure system output response follows a specific reference signal accurately in the steady state. Explain the steady state error. [6 marks]

(c) Let $G(s) = \frac{10}{s^2+5s+10}$ be the forward path transfer function for the system shown in **Figure Q1(c).**

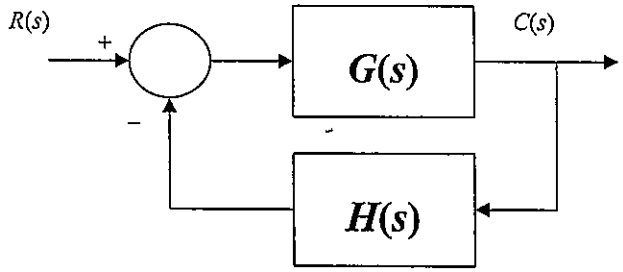

Figure Q1(c)

Find the step error constant and the steady-state error for a unit step input when the system has negative unity feedback. [6 marks]

Continued ...

Question 2

(a) Consider the characteristic equation $\mathbf{s^4 + Ks^3 + 2s^2 + s + 1 = 0}$, analyze the range of K for stability using Routh-Hurwitz stability criterion. [12 marks]

(b) Consider a unity feedback system given in **Figure Q2(b)**.

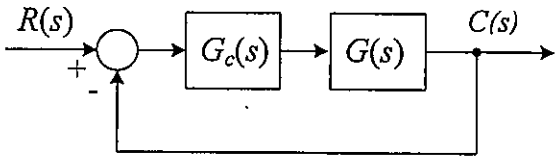

Figure Q2(b)

The plant transfer function is given by $G(s) = \frac{1}{s(s+5)(s+10)}$ and $G_c(s)$ is the transfer function of a controller. Suppose that $G_c(s) = K$ is a Proportional controller with a constant gain $K > 0$. Sketch the root locus with trajectories of the closed-loop roots using the root locus method as K is varied from zero to infinity. The root locus must include the starting and ending points of all branches, root loci on the real axis, angles and centroids of asymptotes and breakaway / break in points. Show all the detail calculation steps.

[13 marks]

Continued ...

Question 3

(a) Describe the general procedure for plotting the Bode Diagrams. [10 marks]

(b) Consider a negative unity feedback control system with the following forward path transfer function

$$G(s) = \frac{40}{s(s+5)(s+8)}$$

(i) Determine the frequency that intercepts with the negative real axis. [7 marks]

(ii) Evaluate the gain margin and analyze for stability and instability of the system through gain margin. [8 marks]

Question 4

(a) Analyze the role of Proportional- Derivative (PD) controller in the performance of a control system. [12 marks]

(b) Design a Proportional- Derivative (PD) controller to be inserted in the forward-path of the system shown in **Figure Q4** that satisfies the following performance specifications: *(Hint: You may first determine the range of K)*

- Proportional constant, $K_P = 1$
- The system with PD controller should be critically damped
- The steady state error due to input $x(t) = tu_s(s)$ should be less than or equal to 5×10^{-4}, where $u_s(s)$ is unit step

[13 marks]

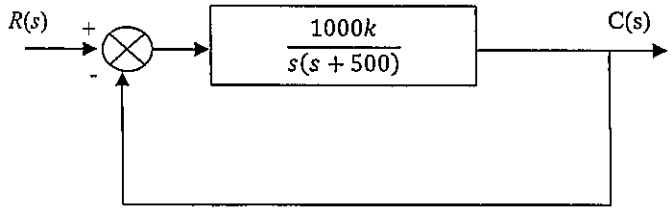

Figure Q4

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APPENDIX

TABLE: **Laplace Transform Pairs**

f(t)	F(s)
Unit impulse $\delta(t)$	1
Unit step u(t)	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ (n = 1, 2, 3, ...)	$\frac{1}{s^n}$
t^n (n = 1, 2, 3, ...)	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$1-\cos \omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t - \sin \omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin \omega t - \omega t \cos \omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega} t \sin \omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t \cos \omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$

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